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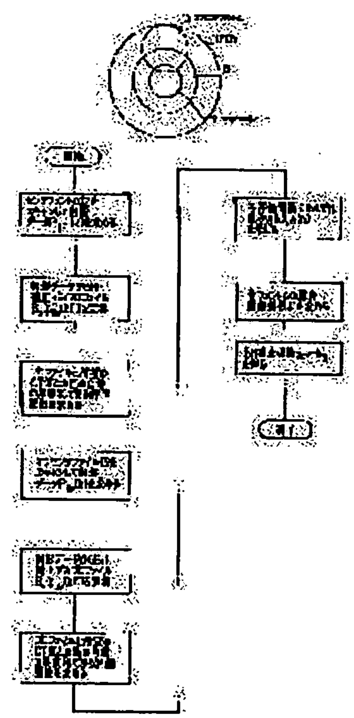
(54) BEAM HARDENING CORRECTING METHOD

(57)Abstract:

PURPOSE: To improve uniformity in the CT values of off-center phantoms by calculating an evaluation function by respectively scanning respective center phantoms and the off-center phantom, adding the respective evaluation functions while applying weight, and obtaining a BH correcting coefficient by calculating the evaluation function obtd. by integrating all the phantoms.

CONSTITUTION: By adding a sum δ of error as the evaluation function obtained by scanning a center phantom 12 and the evaluation function obtained by scanning an off-center phantom 13 while multiplying a weight w(k) by the evaluation functions of the respective phantoms, an evaluation function δ, obtd. by integrating all the phantoms 12 and 13 is calculated and BH correction coefficients b0-b8 are calculated. Thus, in the case of BH correction executed by using the phantoms, even when the off-centered water phantom is used, the uniformity in the CT values of the off-center phantoms can be improved while being balanced with the uniformity in the center water phantom.



LEGAL STATUS

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CLAIMS

[Claim(s)]

[Claim 1] In the beam hardening amendment approach of obtaining a beam hardening correction factor by the performance index (delta) which scanned and obtained the uniform center phantom (12) by which centering was carried out in order to amend distortion by the BH effectiveness produced in X-ray CT The performance index which scanned and obtained said center phantom (12) (delta), The performance index (delta') which synthesized all phantoms (12 13) by multiplying the performance index of each phantom (12 13) by weight (w (k)), and adding to it the performance index which scanned and obtained the uniform off center phantom (13) by which the off center was carried out, respectively is searched for. The beam hardening amendment approach characterized by obtaining a beam hardening correction factor (b0 -b8).

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the BH amendment approach which continues throughout a reconstruction image field and is amended especially on the average about the beam (hardening BH) amendment approach which amends distortion produced according to the beam hardening effectiveness generated in X-ray CT.
[0002]
[Description of the Prior Art] X-ray CT is equipment which detects with a detector the X-ray which was emitted from the X-ray tube and penetrated analyte, and obtains a tomogram. That X-ray spectrum has large attenuation of a low energy part, therefore the part of high energy becomes large relatively, hardening is common knowledge and this phenomenon is known as BH effectiveness as an X-ray penetrates an inspected object and decreases, since the X-ray used for this CT is usually a multicolor X-ray. Projection data become nonlinear according to this BH effectiveness. Change of the projection data based on this BH effectiveness is shown in drawing 6 . In drawing, they are a curve in the ideal condition that 1 is not influenced by the BH effectiveness, and the curve which 2 passed through the organization of analyte and has been influenced of the BH effectiveness. Thus, if it passes through the organization of analyte, the projection data will become nonlinear in response to distortion according to the BH effectiveness.
[0003] Conventionally, nonlinear amendment by this BH effectiveness was performed using the water phantom. Generally, derivation of BH correction factor performed using a water phantom is performed by making into min the sum of the error shown below. The sum delta with error is called for by (1) type.

[0004]
[Equation 1]

$$\delta=\sum_{k=1}^{n}\int_{g_k}^{h_k}\{I(s)-c_k\}^2 ds \qquad \cdots(1)$$

[0005] However, I (s): Image s of the reconfigurated water phantom : Pixel ck : CT valve to make into Taira and others of the phantom (constant). k subtracted ck (in the case of a water phantom, it is 0) which is a CT valve to make into Taira and others of the aforementioned water phantom from image I (s) which carried out data image reconstruction according [the number (1) type of a phantom] to a water phantom -- namely, ck from -- it is the formula which asks for the sum delta of the error value which squared the deviation and carried out accumulation about all n water phantoms. This delta is used as a performance index of BH amendment.
[0006] Since it means that making the sum delta of this error into min had performed BH amendment, it asks by carrying out the partial differential of the minimum value of delta with BH correction factor, as shown in (2) types.
[0007]
[Equation 2]

$$\frac{\partial\delta}{\partial b_m}=0 \qquad \cdots(2)$$

[0008] Here, it is bm. BH correction factor and m are the number of 0-8. In order to perform BH amendment, it asks for projection data Pij' amended by performing an operation like a degree type.
[0009]
Pij'=B0 i-Pij+B1 i-Pij2+B-2i-Pij3 .... (3)
Here, it is projection data (the data of all channels are taken for every view) of a Pij:i channel j view. BH correction factor file B0i, B1i, and B-2i which are the multiplier of the projection data of B0 file [i,

B1i, and B-2i:BH correction factor] (3) equation are called for by solving the following simultaneous equations.
[0010]
[Equation 3]

$$\left.\begin{array}{l} B_{0i}=b_0+b_3Q_i+b_6Q_i^2 \\ B_{1i}=b_1+b_4Q_i+b_7O_i^2 \\ B_{2i}=b_2+b_5Q_i+b_8Q_i^2 \end{array}\right\} \quad \cdots(4)$$

[0011] Here, it is Qi. : Path length b0 -b8 of a bow tie filter : BH correction factor b0 -b8 of BH ********** BH amendment can be performed by asking.
[0012] If image reconstruction is carried out from the projection data Pij of a certain phantom k (k) and the value of the image profile in Pixel s is set to Bs (Pij (k) '), a degree type will be obtained with the linearity of image reconstruction.
[0013]
[Equation 4]

$$B_s(P_{ij}(k)')=b_0+f_{0k}+\sum_{m=0}^{8}b_m f_{mk} \quad \cdots(5)$$

[0014] (5) Bs (Pij (k) ') of a formula is equivalent to I (s) of (1) type. Thus, the sum delta of the error value of n phantoms which evaluate a difference with a CT valve to press down the value and cupping of a profile for which it asked, and make into Taira and others in the range of [gk and hk] is called for by the degree type.
[0015]
[Equation 5]

$$\delta=\sum_{k=1}^{n}\int_{g_k}^{h_k}\{B_s(P_{ij}(k)')-c_k\}^2 ds \quad \cdots(6)$$

[0016] Here, it is ck. The partial differential of the sum delta of the error of CT valve ** made into the target of Phantom k is carried out by (7) equations, and simultaneous equations are obtained.
[0017]
[Equation 6]

$$\frac{\partial\delta}{\partial b_m}=0 \ (m=0\sim8) \quad \cdots(7)$$

[0018] (7) Solve the simultaneous equations obtained from the equation and it is bm. It asks. Here, fmk of (5) types is a value shown in (8) types, respectively.
[0019]
[Equation 7]

$$\left.\begin{aligned} f_{0k}&=Bs(P_{ij}(k)) \\ f_{1k}&=Bs(P_{ij}(k)^2) \\ f_{2k}&=Bs(P_{ij}(k)^3) \\ f_{3k}&=Bs(Q_iP_{ij}(k)) \\ f_{4k}&=Bs(Q_iP_{ij}(k)^2) \\ f_{5k}&=Bs(Q_iP_{ij}(k)^3) \\ f_{6k}&=Bs(Q_i^2P_{ij}(k)) \\ f_{7k}&=Bs(Q_i^2P_{ij}(k)^2) \\ f_{8k}&=Bs(Q_i^2P_{ij}(k)^3) \end{aligned}\right\} \quad \cdots(8)$$

[0020]
[Problem(s) to be Solved by the Invention] The homogeneity phantom from which the magnitude by which centering was usually carried out in this phantom k differs is used conventionally, and it is BH correction factor b0 -b8. It was asking. That is, although it was asking for raising the homogeneity of the water phantom from which the magnitude put on the center of a reconstruction image field differs in derivation of BH correction factor as a performance index, the homogeneity of the water phantom by which the off center was carried out might worsen.
[0021] This invention was made in view of the above-mentioned point, and the purpose is realizing BH correction method which can be raised while balancing the homogeneity of the water phantom which put the homogeneity of the CT valve of an off center phantom on the center, also when it uses with the water phantom which put the water phantom by which the off center was carried out on the center.
[0022]
[Means for Solving the Problem] In order that this invention which solves the aforementioned technical problem may amend distortion by the BH effectiveness produced in X-ray CT, In the BH amendment approach of obtaining BH correction factor by the performance index which scanned and obtained the uniform center phantom by which centering was carried out The performance index which synthesized all phantoms by multiplying the performance index of each phantom by weight, and adding to it the performance index which scanned and obtained said center phantom, and the performance index which scanned and obtained the uniform off center phantom by which the off center was carried out, respectively is searched for. It is characterized by obtaining BH correction factor.
[0023]
[Function] Each center phantom is scanned, a performance index is searched for, then an off center phantom is scanned, the performance index is searched for, weight is added and added to each performance index, respectively, the performance index synthesizing all phantoms is calculated, and BH correction factor is obtained.
[0024]
[Example] Hereafter, the example of the approach of this invention is explained to a detail with reference to a drawing. Drawing 3 is the plot plan of the phantom for approach operation of one example of this invention. In drawing, 11 is FOV (field of view) which is the range which should be observed. The center phantom by which 12 is used for evaluation from the former for BH amendment, and 13 are the newly added uniform off center phantoms by which the off center was carried out.
[0025] It is Pijc about the amended [BH] projection data of the center phantom 12 which is a uniform phantom by which centering was carried out. (k) It is Pijo about the amended [BH] projection data of

the off center phantom 13 which is a uniform phantom by which the off center was carried out by considering as '. (k) It considers as '. (5) Ask for sum delta' of the error at the time of adding the off center phantom 13 by (9) types which considered and added weight w (k) which is different in the profile which used and obtained the off center phantom 13, respectively to the profile obtained using the center phantom 12 by the formula.

[0026]

[Equation 8]

$$
\begin{aligned}
\delta' &= \sum_{k=1}^{n} w(k) \int_{g_k}^{h_k} \{B_s(P_{ij}(k)') - c_k\}^2 ds \\
&= \sum_{k=1}^{n-1} w(k) \int_{g_k}^{h_k} \{B_s(P_{ijc}(k)') - c_k\}^2 ds \\
&\quad + w(n) \int_{g_n}^{h_n} \{B_s(P_{ijo}(n)') - c_n\}^2 ds \qquad \cdots(9)
\end{aligned}
$$

[0027] Here, it is Pijc. (k) ': Amended [BH] projection data Pijo of the uniform center phantom 12 (k) ': Solve the amended [BH] projection data (9) type of the uniform off center phantom 13 using the aforementioned (7) types and (8) types, and it is the BH correction factor bm. It asks.

[0028] Drawing 4 is a flow chart which shows the outline of the approach of this example. Since the flow chart of drawing 1 and drawing 2 explains the detail of a procedure, explanation is omitted about drawing 4 . Next, the procedure of asking for BH correction factor described above is explained using the flow chart of drawing 1 and drawing 2 . Drawing 1 and drawing 2 divide one flow chart on account of space.

[0029] An empty scan is carried out in the condition of not placing the measuring object-ed [step 1], and they are the data for the correction by sensitiveness of a detector, and the path length data Qi of a bow tie filter. It extracts.

[0030] A step 2n piece phantom is chosen and n-1 piece is used as a center phantom 12, using one piece as an off center phantom 13. The center phantom 12 is used from No. 1 to No. n-1, replacing it one by one.

[0031] The number of step 3 phantom is made into No. k, and it sets with k= 0. (The n-1:center [k= 1 -] phantom 12, k=n: Off center phantom)

Step 4 k+1 is set to k which will seemingly be new, and the center phantom 12 of No. 1 is used in the beginning.

[0032] Step 5 It scans by putting the center phantom 12 of No. k (No. one to n-1) on an image reconstruction field one by one.

[0033] Data to projection data Pijc obtained with step 6 scan It calculates and asks for (k).

Step 7 projection data Pijc An image reconstruction operation is performed using (k) and image data is obtained.

[0034] The step 8 number m is set with 0.

Path length Qi of the bow tie filter for which it asked at step 9 step 1 It uses and fmk is calculated from (4) types, (5) types, etc.

[0035] It is confirmed whether step 10m was set to 8. If it is not 8, it progresses to step 11. If it is 8, it will progress to step 12.

[0036] Step 11m+ 1 is set to new m and it returns to step 9.

Step 12 It is confirmed whether k was set to n-1. If it is not n-1, it returns to step 4. Since the scan to the center phantom 12 was finished when set to n-1, it progresses to step 13 shown in drawing 2 .

[0037] Step 13 It scans by putting the off center phantom 13 of No. n on an image reconstruction field. Data to projection data Pijo obtained with step 14 scan It calculates and asks for (n).

[0038] Step 15 projection data Pijo An image reconstruction operation is performed using (n) and image data is obtained.

The step 16 number m is set with 0.
[0039] Path length Qi of the bow tie filter for which it asked at step 17 step 1 It uses and fmn made into k=n of fmk in (5) types is calculated from (4) types and (5) types.
[0040] It is confirmed whether step 18m was set to 8. If it is not 8, it progresses to step 19. If it has become, it will progress to step 20.
[0041] Step 19m+ 1 is set to new m and it returns to step 17.
The data of fmk obtained at step 20 step 9 and step 17 are multiplied by weight w (k), respectively.
[0042] Step 21 matrix is derived using a degree type.
[0043]
[Equation 9]

$$\sum_k f_{0k} \times (f_{0k}\text{の関数}) \sim \sum_k f_{8k} \times (f_{8k}\text{の関数})$$

$$= \sum_k c_k \times (f_{0k}\text{の関数}) \sim \sum_k c_k \times (f_{8k}\text{の関数}) \quad \cdots (10)$$

[0044] The matrix searched for from step 22 (10) type is dispelled.
Step 23BH correction factor b0 -b8 It obtains.
[0045] As explained above, when deriving BH correction factor according to this example, homogeneity can be raised by including the profile of an off center phantom into the sum delta of the error made into min, balancing other center phantoms, as shown in drawing 4 . In drawing 5 , in conventional equipment, a (b) Fig. is a curvilinear Fig. of the profile of the off center phantom at the time of carrying out BH amendment using a center phantom, and has taken the CT valve on the pixel and the axis of ordinate along the axis of abscissa. (b) Drawing is a curvilinear Fig. which made the same the axis of abscissa and the axis of ordinate, and expresses the profile of the off center phantom at the time of performing BH correction factor derivation to a center phantom including an off center phantom, as the example showed. With drawing, compared with the case of the former of a (b) Fig., as for the case of the off center phantom in the (b) Fig. of an example, the CT valve is Taira and others so that clearly.
[0046]
[Effect of the Invention] As explained to the detail above, also when the water phantom by which the off center was carried out is used in BH amendment performed using a phantom according to this invention, it can be made to improve now, balancing the homogeneity of the water phantom which put the homogeneity of the CT valve of an off center phantom on the center, and practical effectiveness is large.

[Translation done.]

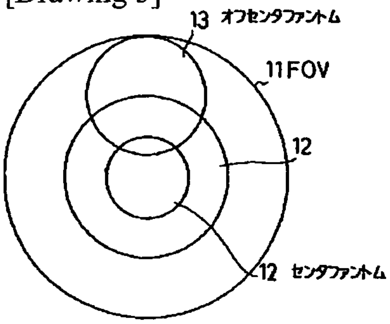
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the first portion which divided into two the flow chart which shows the procedure of the approach of one example of this invention.
[Drawing 2] It is the second half section of the flow chart divided into two.
[Drawing 3] It is the plot plan of a center phantom and an off center phantom.
[Drawing 4] It is the flow chart which shows the outline of the approach of the example of this invention.
[Drawing 5] It is drawing showing the profile of the off center phantom at the time of performing the conventional BH amendment and BH amendment of this invention, and, in the former [Fig. / (b)], a (b) Fig. is drawing in the case of this invention.
[Drawing 6] It is drawing showing change of the projection data based on the BH effectiveness.
[Description of Notations]
12 Center Phantom
13 Off Center Phantom
delta, delta' Performance index
w (k) Weight
b0 -b8 BH correction factor

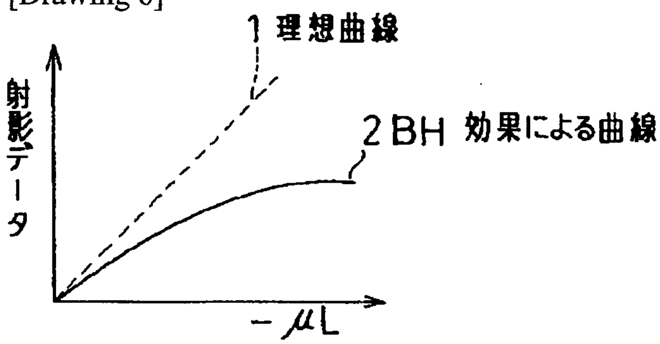
[Translation done.]

DRAWINGS

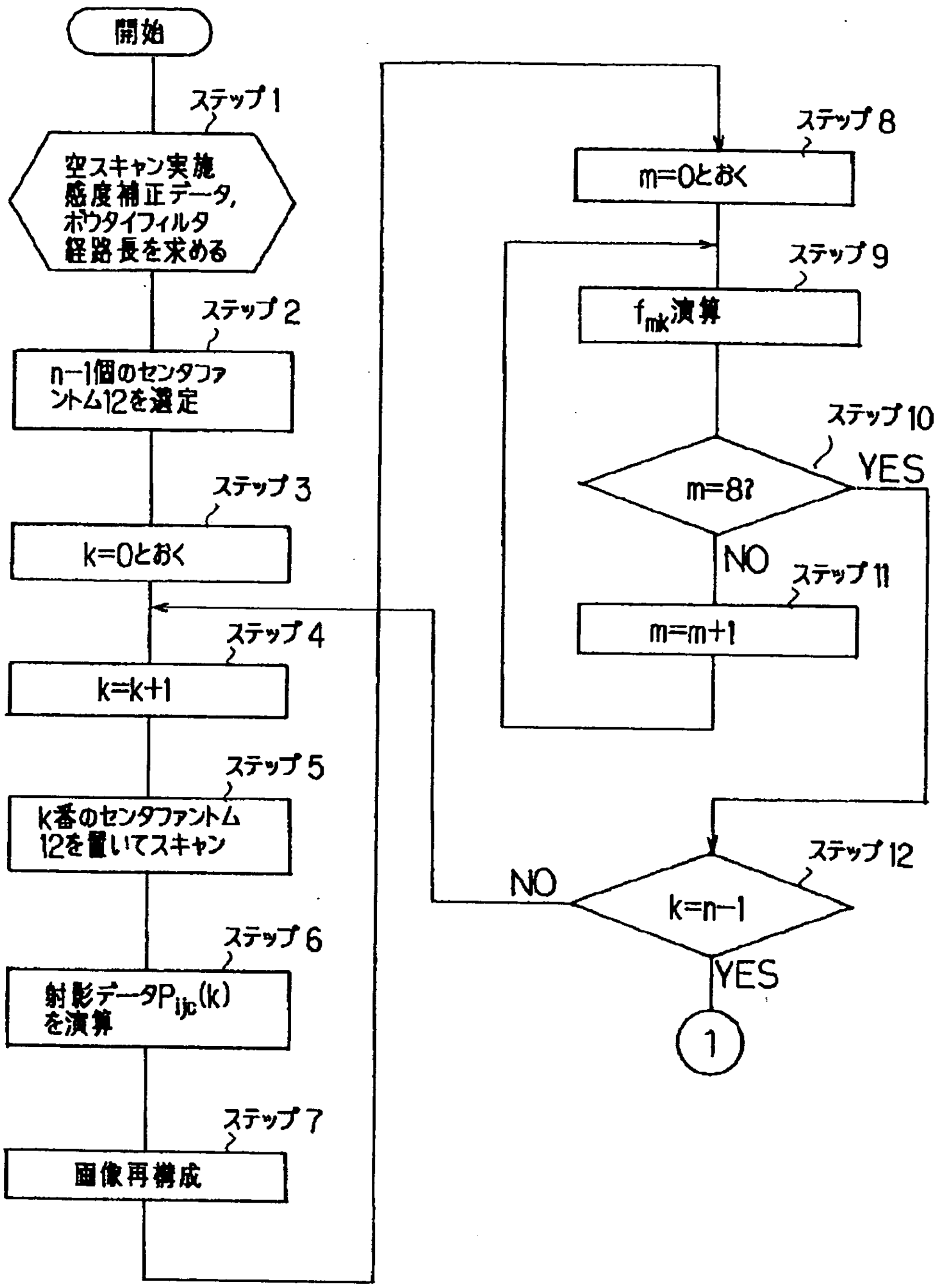
[Drawing 3]



[Drawing 6]

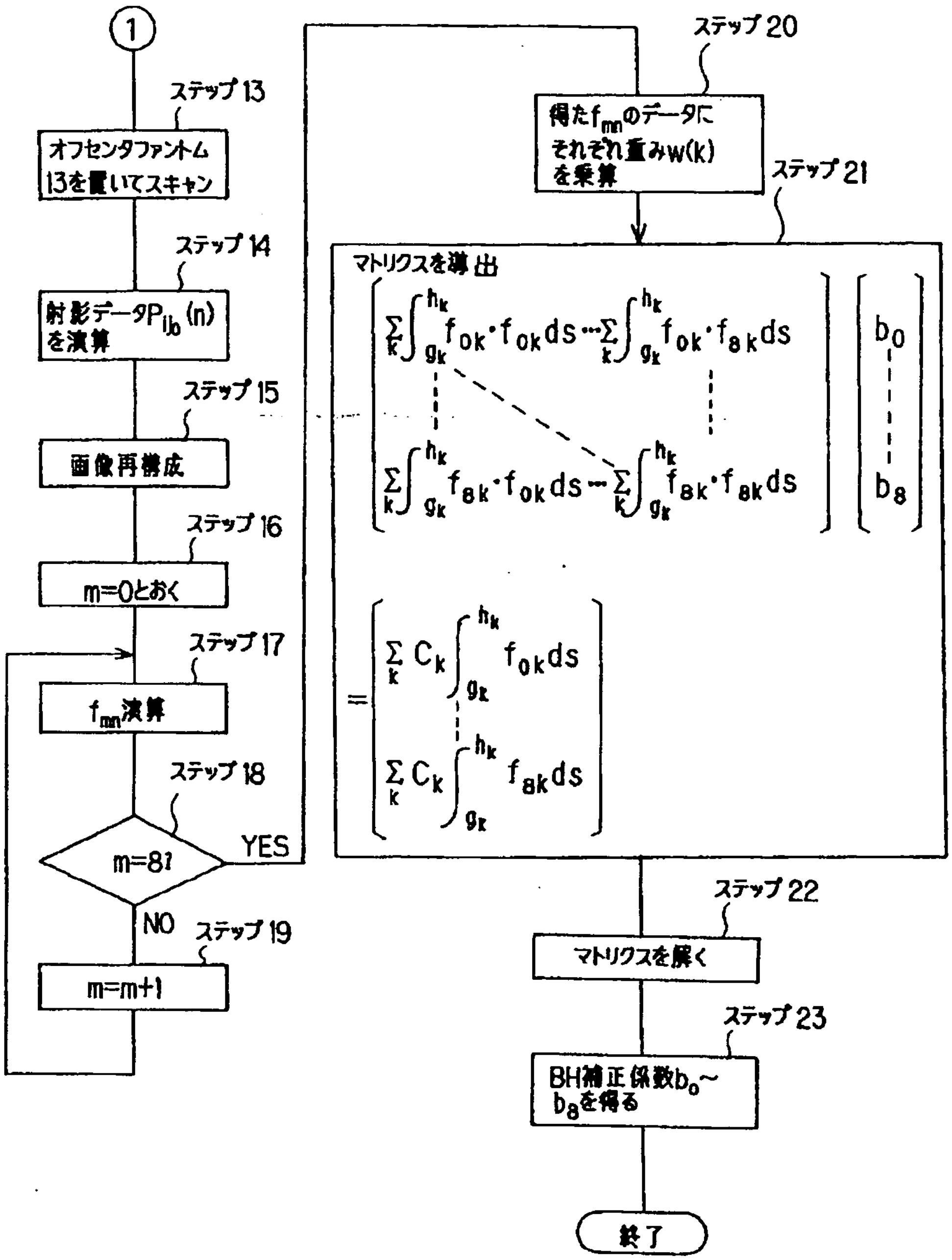


[Drawing 1]



開始
ステップ1
空スキャン実施
感度補正データ,
ボウタイフィルタ
経路長を求める
ステップ2
n−1個のセンタファントム12を選定
ステップ3
k=0とおく
ステップ4
k=k+1
ステップ5
k番のセンタファントム12を置いてスキャン
ステップ6
射影データPijc(k)を演算
ステップ7
画像再構成
ステップ8
m=0とおく
ステップ9
fmk演算
ステップ10
m=8?
YES
NO
ステップ11
m=m+1
ステップ12
k=n−1
NO
YES
1

[Drawing 2]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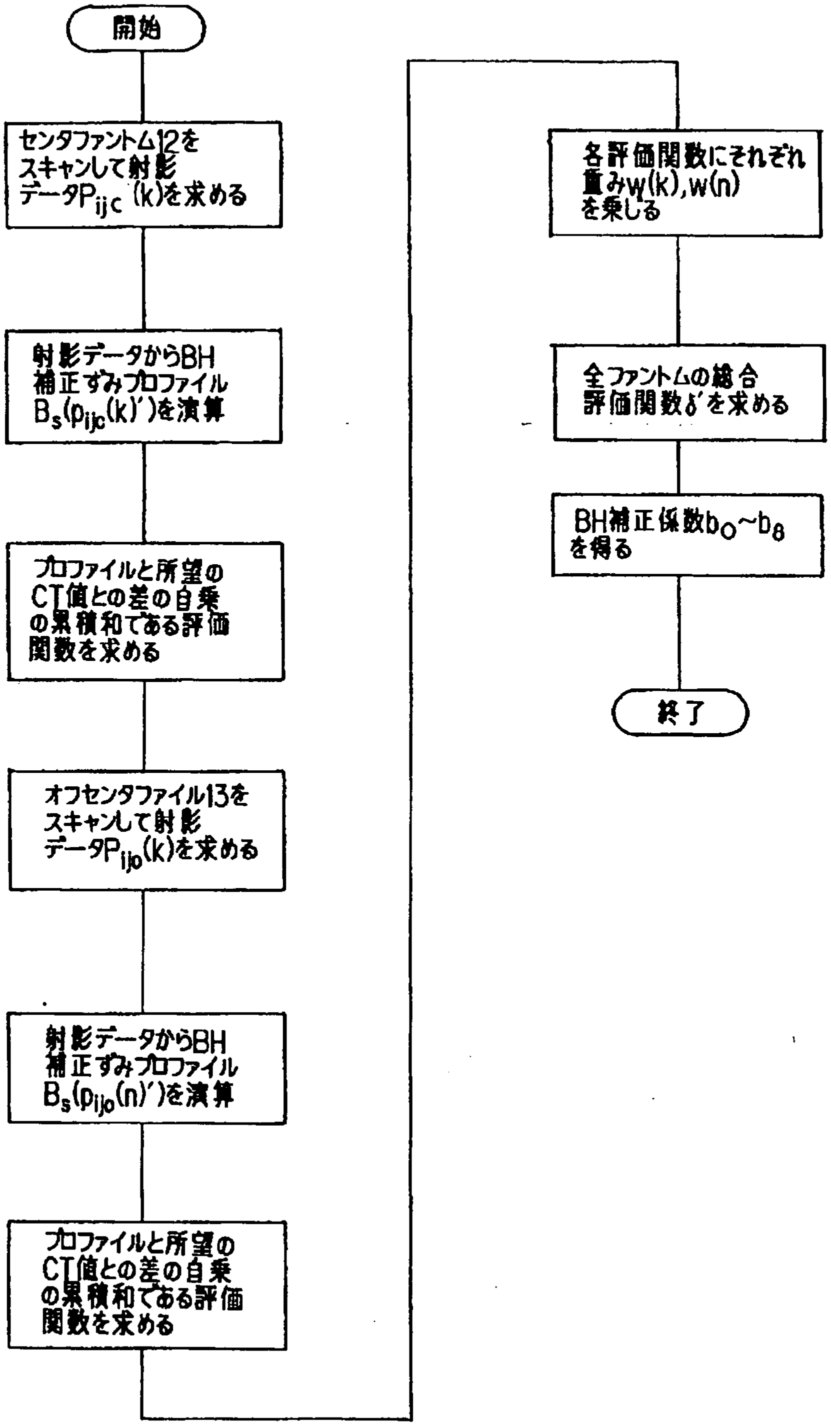
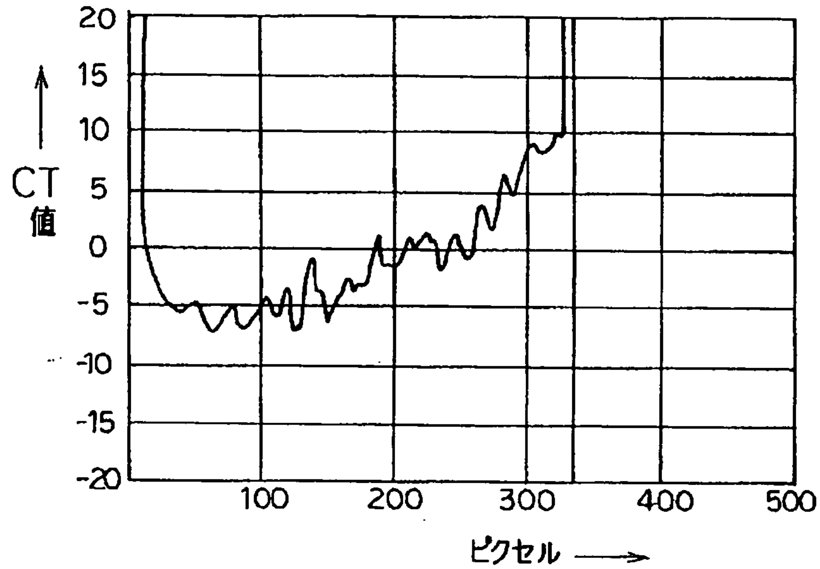
ステップ13
オフセンタファントム13を置いてスキャン
ステップ14
射影データ$P_{ijb}(n)$を演算
ステップ15
画像再構成
ステップ16
m=0とおく
ステップ17
f_{mn}演算
ステップ18
m=8?
YES
NO
ステップ19
m=m+1
ステップ20
得たf_{mn}のデータにそれぞれ重みw(k)を乗算
ステップ21
マトリクスを導出
$$\begin{bmatrix} \sum_k \int_{g_k}^{h_k} f_{0k}\cdot f_{0k}\,ds & \cdots & \sum_k \int_{g_k}^{h_k} f_{0k}\cdot f_{8k}\,ds \\ \vdots & \ddots & \vdots \\ \sum_k \int_{g_k}^{h_k} f_{8k}\cdot f_{0k}\,ds & \cdots & \sum_k \int_{g_k}^{h_k} f_{8k}\cdot f_{8k}\,ds \end{bmatrix} \begin{bmatrix} b_0 \\ \vdots \\ b_8 \end{bmatrix} = \begin{bmatrix} \sum_k C_k \int_{g_k}^{h_k} f_{0k}\,ds \\ \vdots \\ \sum_k C_k \int_{g_k}^{h_k} f_{8k}\,ds \end{bmatrix}$$
ステップ22
マトリクスを解く
ステップ23
BH補正係数b_0~b_8を得る
終了

[Drawing 4]


開始
センタファントム12をスキャンして射影データPijc (k)を求める
射影データからBH補正ずみプロファイルBs(pijc(k)')を演算
プロファイルと所望のCT値との差の自乗の累積和である評価関数を求める
オフセンタファイル13をスキャンして射影データPijo(k)を求める
射影データからBH補正ずみプロファイルBs(pijo(n)')を演算
プロファイルと所望のCT値との差の自乗の累積和である評価関数を求める
各評価関数にそれぞれ重みw(k),w(n)を乗じる
全ファントムの総合評価関数δを求める
BH補正係数b0~b8を得る
終了

[Drawing 5]

(イ)



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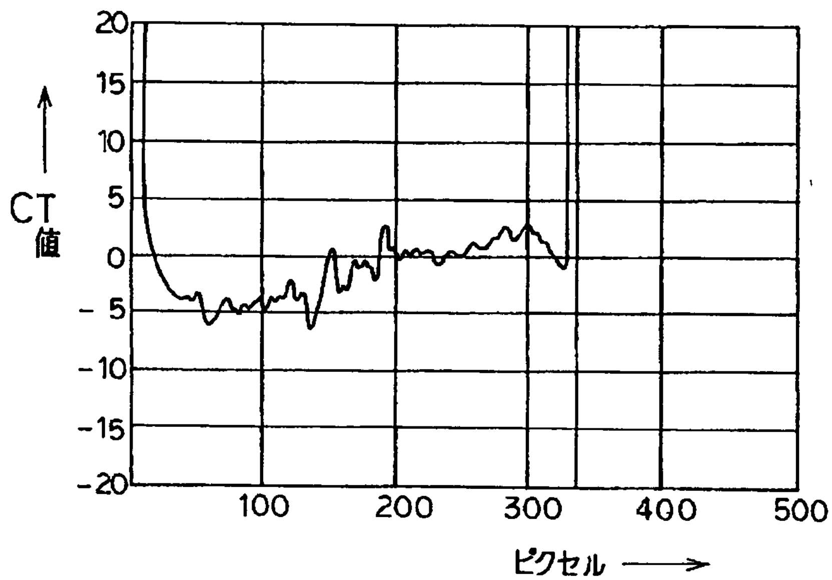

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